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Signed, this 16th day of May, 2005

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[Name of Document] Specification

[Title of the Invention] Oil-diluting Fuel Estimating Apparatus and Internal Combustion Engine Control System Using the Same

[Claims]

[Claim 1] An oil-diluting fuel estimating apparatus comprising:

increase quantity calculating means for calculating the increase quantity of oil-diluting fuel that leaks out through a clearance between a piston and a cylinder and dilutes engine oil, from an engine temperature, engine rotational speed, and engine load; and

oil-diluting fuel quantity calculating means for calculating the quantity of oil-diluting fuel that dilutes the engine oil by summing up the increase quantities of oil-diluting fuel calculated by the increase quantity calculating means.

[Claim 2] An oil-diluting fuel estimating apparatus comprising:

increase quantity calculating means for calculating the increase quantity of oil-diluting fuel that leaks out through a clearance between a piston and a cylinder and dilutes engine oil, from an engine temperature, engine rotational speed, and engine load;

decrease quantity calculating means for calculating the decrease quantity of oil-diluting fuel quantity from an engine temperature and engine rotational speed; and

oil-diluting fuel quantity calculating means for calculating the quantity of oil-diluting fuel that dilutes the engine oil by summing up the oil-diluting fuel increase quantity calculated by the increase quantity calculating means and the oil-diluting fuel decrease quantity calculated by the decrease quantity calculating means.

[Claim 3] The oil-diluting fuel estimating apparatus according to claim 1 or 2, characterized in that the engine temperature in the increase quantity calculating means is a cylinder wall temperature.

[Claim 4] The oil-diluting fuel estimating apparatus according to claim 2, characterized in that the engine temperature in the decrease quantity calculating means is an engine oil temperature.

[Claim 5] The oil-diluting fuel estimating apparatus according to any one of claims 1 to 4, characterized in that when a fuel in which alcohol is mixed in gasoline is used, an alcohol concentration calculation permitting condition for permitting the calculation of alcohol concentration is set in accordance with the oil-diluting fuel quantity.

[Claim 6] The oil-diluting fuel estimating apparatus according to claim 5, characterized in that when by the alcohol concentration calculation permitting condition, at least either one of the condition that the oil-diluting fuel quantity is not larger than a predetermined value and the condition that a variation in oil-diluting fuel quantity is not larger than a predetermined value is satisfied, the

calculation of alcohol concentration is permitted.

[Claim 7] The oil-diluting fuel estimating apparatus according to any one of claims 1 to 6, characterized in that the oil-diluting fuel quantity is corrected in accordance with the quantity of fuel injected actually from an engine.

[Claim 8] An internal combustion engine control system characterized by correcting the fuel injection quantity in accordance with the oil-diluting fuel quantity calculated by the oil-diluting fuel estimating apparatus described in any one of claims 1 to 6.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to an oil-diluting fuel estimating apparatus and an internal combustion engine control system using the apparatus.

[0002]

[Prior Art]

In an internal combustion engine, what is called oil dilution in which fuel leaks out through a clearance between a piston and a cylinder and dilutes engine oil may sometimes take place.

[0003]

As measures for restraining the occurrence of such oil dilution, a control system has conventionally been known in which in the case where fuel injection is effected in the intake stroke in in-cylinder direct fuel injection type

internal combustion engine, fuel injection start timing is changed based on a parameter representing ease of adhesion of fuel to the internal combustion engine (refer to Patent Document 1).

[0004]

[Patent Document 1]

Japanese Patent Application *Kokai* Publication No. 2002-13428 (pages 3 -4, Figure 3)

[0005]

[Problems to be Solved by the Invention]

However, the above-described conventional control system takes no account of the quantity of oil-diluting fuel that leaks out through the clearance between the piston and the cylinder, being mixed in the engine oil, and dilutes the engine oil. Therefore, if the fuel mixed in the engine oil evaporates from the engine oil and is sucked into an intake system through a blowby system etc., the air-fuel ratio becomes excessively rich (fuel rich), which may exert an adverse influence on the operability and emission control.

[0006]

Also, even if fuel injection start timing is changed based on a parameter representing ease of adhesion of fuel to the internal combustion engine, oil dilution cannot be prevented completely. In the case where the quantity of fuel leaking out through the clearance between the piston and the cylinder is large, the quantity of fuel burning actually in a combustion chamber decreases, so that the air-

fuel ratio becomes excessively lean (air rich), which may exert an adverse influence on the operability and emission control.

[0007]

That is to say, it is important to exactly grasp the quantity of oil-diluting fuel and to control the internal combustion engine in accordance with the quantity of oil-diluting fuel.

[0008]

[Means of Solving the Problems]

An oil-diluting fuel quantity estimating apparatus in accordance with the present invention includes increase quantity calculating means for calculating the increase quantity of oil-diluting fuel that leaks out through the clearance between the piston and the cylinder and dilutes the engine oil, from an engine temperature, engine rotational speed, and engine load, and oil-diluting fuel quantity calculating means for calculating the quantity of oil-diluting fuel that dilutes the engine oil by summing up the increase quantities of oil-diluting fuel calculated by the increase quantity calculating means.

[0009]

[Effects of the Invention]

According to the present invention, the quantity of oil-diluting fuel that dilutes the engine oil can be grasped exactly regardless of operating pattern and environment.

[0010]

[Embodiments of the Invention]

One embodiment of the present invention will now be explained in detail with reference to the accompanying drawings.

[0011]

Figure 1 shows a schematic configuration of an internal combustion engine control system in accordance with one embodiment of the present invention. A combustion chamber 2 of an engine body 1 is connected with an intake air passage 4 via an intake valve 3 and with an exhaust passage 6 via an exhaust valve 5.

[0012]

In the intake air passage 4, an air cleaner 7, an air flowmeter 8 for detecting the quantity of intake air, a throttle valve 9 for controlling the quantity of intake air, and a fuel injection valve 11 for injecting fuel into the intake air are disposed.

[0013]

The fuel injection valve 11 injects fuel into the intake air in accordance with operating conditions by means of an injection command signal sent from an engine control unit 12 (hereinafter abbreviated to ECU) so that a predetermined air-fuel ratio is provided.

[0014]

In the exhaust passage 6, an oxygen concentration sensor 13 for detecting the concentration of oxygen in exhaust gas and a three-way catalyst 14 are disposed.

[0015]

The three-way catalyst 14 can purify NOx, HC and CO in exhaust gas at the same time with the maximum conversion efficiency in the case where the air-fuel ratio lies in what is called a window around the stoichiometric air-fuel ratio. Therefore, the ECU 12 carries out feedback control of air-fuel ratio so that the air-fuel ratio of exhaust gas swings with a fixed period within the aforementioned window based on the output from the oxygen concentration sensor 13 provided on the upstream side of the three-way catalyst 14.

[0016]

Also, the ECU 12 receives signals from a water temperature sensor 15 for sensing the temperature of cooling water for the engine body 1, a crank angle sensor 16 for sensing an engine rotational speed, an outside air temperature sensor 17 for sensing an outside air temperature, and a vehicle speed sensor 18 for sensing a vehicle speed.

[0017]

When what is called oil dilution, in which some of the fuel adheres to the inside wall surface of the cylinder and leaks out through the clearance between the piston and the cylinder to dilute an engine oil during the engine operation, takes place, the quantity of fuel burning in the combustion chamber 2 decreases. Therefore, the air-fuel ratio becomes excessively lean (air rich), which may exert an adverse influence on the operability and emission control. Also, if the fuel that dilutes the engine oil by means of oil

dilution evaporates from the engine oil and is sucked into an intake system through a blowby system etc., the air-fuel ratio becomes excessively rich (fuel rich), which may exert an adverse influence on the operability and emission control.

[0018]

Thereupon, in the oil-diluting fuel estimating apparatus in accordance with a first embodiment of the present invention, an oil-diluting fuel quantity OF of fuel mixed in the engine oil by means of oil dilution is estimated by a procedure described below.

[0019]

A flowchart shown in Figure 2 shows the whole of a process for determining the oil-diluting fuel quantity OF, the process being executed every predetermined time.

[0020]

In Step 1 (hereinafter, Step is abbreviated to S) consisting of a first subroutine (described later in detail), an increase quantity A of oil-diluting fuel quantity is calculated.

[0021]

In S2 consisting of a second subroutine (described later in detail), a decrease rate B of oil-diluting fuel quantity is calculated.

[0022]

In S3, a variation quantity COF of oil-diluting fuel quantity is calculated by using the increase quantity A of oil-diluting fuel quantity calculated in S1 and the decrease

rate B of oil-diluting fuel quantity calculated in S2. In this example, $OF_{n-1}$ is the oil-diluting fuel quantity calculated in the previous cycle. In S4, the oil-diluting fuel quantity OF is calculated.

[0023]

Figure 3 shows a control flow of the aforementioned first subroutine.

[0024]

In S11, a fuel fall rate C, which is an increase rate of the increase quantity A, is calculated by referring to an MOFD map (described later). Figure 4 shows a characteristic example of the MOFD map. This MOFD map is designed to calculate the fuel fall rate C from a cylinder wall temperature TC (described later in detail) used as an engine temperature and an engine rotational speed Ne. The fuel fall rate C increases as the engine rotational speed decreases, and also the fuel fall rate C increases as the cylinder wall temperature TC becomes lower. The reason for this is that it is thought that in a low engine rotation, the gas motion is lower, and the evaporation and atomization of fuel are poor, so that the fuel is more likely to adhere to the wall surface. Also, the cylinder wall temperature TC depends on the volatility of fuel.

[0025]

In S12, a load correction ratio D is calculated by referring to a load correction table (described later). Figure 5 shows a characteristic example of the load

correction table. The load correction table is designed to calculate the load correction ratio D from a base fuel injection quantity Tp (described later) determined from an intake air quantity Qa obtained from the output of the air flowmeter 8 as an engine load and the engine rotational speed Ne. At higher load, the proportion of unburned fuel increases, so that the load correction ratio D takes a larger value. The reason for this is that it is thought that a change in fuel volatility caused by a pressure has an influence.

[0026]

In S13, the increase quantity A is calculated by using the fuel fall rate C, the load correction ratio D, the engine rotational speed Ne, and a fuel injection quantity Te determined by engine operating conditions as an engine load.

[0027]

Figure 6 shows a control flow of the aforementioned second subroutine. In the second subroutine, in S21, the decrease rate B, which is an evaporation ratio of oil-diluting fuel from the engine oil, is calculated by referring to an MOFU map (described later). Figure 7 shows a characteristic example of the MOFU map. This MOFU map is designed to calculate the decrease rate B from an oil temperature TO and the engine rotational speed Ne. The correlation between the decrease rate and the oil temperature TO is such that because of the volatility of fuel, the decrease rate B increases as the oil temperature

TO becomes higher. Also, the correlation between the decrease rate and the engine rotational speed Ne is such that the decrease rate B increases as the engine rotational speed Ne increases because the evaporation of fuel in the engine oil is promoted by the circulating agitation of oil with an oil pump and the oil agitation caused by a counterweight of a crankshaft.

[0028]

Next, Figure 8 shows a control flow for predicting the cylinder wall temperature TC used for calculating the increase quantity A.

[0029]

First, in S31, it is judged whether or not the engine is in an engine starting operation or in an operation of first supplying electricity to the ECU 12. In the case of the engine starting operation or the operation of first supplying electricity to the ECU 12, the control proceeds to S32, where an initial value $TC_0$ of the cylinder wall temperature TC is set so as to be equal to an engine cooling water temperature Tw for preparation for temperature increase in the calculation in the next cycle.

[0030]

If it is judged in S31 that neither the engine starting operation nor the ECU first energizing operation is detected, the control proceeds to S33, where it is judged whether or not a fuel cutoff operation is in progress in the engine. If the engine is under the fuel cutoff operation, the

control proceeds to S34, and if the engine is not under the fuel cutoff operation, the control proceeds to S35.

[0031]

When the engine is in the fuel cutoff state, the cylinder wall temperature TC converges toward the engine cooling water temperature Tw. In S34, therefore, a temperature increase balance temperature TCH from the engine cooling water temperature Tw is set so as to be equal to zero (TCH = 0).

[0032]

On the other hand, when the engine is not in the fuel cutoff state, in S35, the temperature increase balance temperature TCH, which is a temperature difference between the cylinder wall temperature TC and the engine cooling water temperature Tw, is calculated by referring to an MTCH map (described later). Figure 9 shows a characteristic example of the MTCH map. This MTCH map is designed to calculate the temperature increase balance temperature TCH by using the engine rotational speed Ne and the base fuel injection quantity Tp. The temperature increase balance temperature TCH correlates strongly with the combustion temperature. Therefore, the temperature increase balance temperature TCH takes a larger value as the engine rotational speed increases and as the base fuel injection quantity Tp, namely, the engine load increases.

[0033]

In S36, a temperature change rate KTC corresponding to

a time constant of temperature is calculated by referring to a KTC map (described later). Figure 10 shows a characteristic example of the KTC map. This KTC map is designed to calculate the temperature change rate KTC by using the engine rotational speed Ne and the base fuel injection quantity Tp. The temperature change rate KTC is subjected to a great influence of the engine rotational speed Ne because the gas flow velocity is predominant in the heat transmission to cylinder wall. Moreover, the temperature change rate KTC has sensitivity to the base fuel injection quantity Tp or the engine load because of the influence on heat transmission by the pressure. Thus, the temperature change rate KTC takes a larger value as the engine rotational speed Ne increases and as the base fuel injection quantity Tp increases.

[0034]

In this embodiment, a method has been proposed in which the temperature increase balance temperature TCH and the temperature change rate KTC are calculated by using the map of the engine rotational speed Ne and the base fuel injection quantity Tp. However, if the required accuracy is relatively low, it is possible to prepare calculation tables based on the intake air quantity Qa, which is the detection signal from the air flowmeter, respectively, for TCH and KTC and to determine TCH and KTC by using the corresponding calculation table.

[0035]

Next, in S37, an instantaneous predicted temperature DTC is determined from the temperature increase balance temperature TCH and the temperature change rate KTC. This predicted temperature DTC represents a temperature difference from the engine cooling water temperature Tw, and is given by the equation $DTC_n = DTC_{n-1} + (TCH - DTC_{n-1}) \times KTC$. This equation is in the form of a first order lag. The predicted temperature DTC follows the temperature increase balance temperature TCH with a first order lag. The form of first order is employed because it is thought that the temperature varies theoretically with a constant rate because of balance with escape of heat. The predicted temperature was regarded as having a rising waveform similar to a rising waveform of a valve temperature which was measured by the inventors of the present invention. In the above equation, $DTC_{n-1}$ is a predicted temperature calculated in the previous calculation cycle.

[0036]

In S38, a value obtained by adding the predicted temperature $DTC_n$ calculated in S37 to the engine cooling water temperature Tw is taken as the cylinder wall temperature $TC_n$. Then, the prediction of the cylinder wall temperature TC is finished. That is to say, each of the temperature increase balance temperature TCH and the predicted temperature DTC is an amount of temperature increase from the engine cooling water temperature Tw, and therefore the engine cooling water temperature Tw is added

finally.

[0037]

In this embodiment, an example in which the cylinder wall temperature TC is predicted has been shown. This is because the system is provided at a low cost. To provide higher accuracy, it is optional to employ a temperature sensor embedded in the cylinder to directly sense the cylinder wall temperature.

[0038]

Next, Figure 11 shows a control flow for predicting the oil temperature TO used for calculating the oil decrease rate B (the evaporation rate of oil-diluting fuel) by using the MOFU map of Figure 7.

[0039]

In S41, it is judged whether or not the engine is in an engine starting operation or in an operation of first supplying electricity to the ECU 12. In the case of the engine starting operation or the operation of first supplying electricity to the ECU 12, the control proceeds to S42, where a value $TO_0$ is set so as to be equal to the engine cooling water temperature Tw.

[0040]

If it is judged in S41 that neither the engine starting operation nor the ECU first energizing operation is detected, the control proceeds to S43.

[0041]

In S43, a heat flow quantity TTW of the engine oil and

the engine cooling water is calculated by using the engine cooling water temperature Tw, TTWS, and a previous oil temperature $TO_{n-1}$ at the calculation time in the previous cycle as given by the equation $TTW_n = (Tw - TO_{n-1}) \times TTWS$. That is to say, the heat transfer quantity is proportional to a temperature difference, and is a function of a flow velocity. Therefore, in this equation, the temperature difference is multiplied by TTWS determined from the engine rotational speed Ne.

[0042]

Figure 12 shows a characteristic example of a TTWS calculation table. TTWS takes a larger value in proportion to the engine rotational speed Ne. The engine rotational speed Ne is used to calculate TTWS because the heat transfer between the engine cooling water or the cylinder block and cylinder head, which are in contact with engine cooling water, and engine oil is proportional to the engine rotational speed Ne that turns the oil pump. Also, heat transmitted from the oil pan can be taken into account by raising the characteristic of Figure 12 by an appropriate amount.

[0043]

In S44, a heat flow quantity TTC with combustion is calculated by using the engine cooling water temperature Tw, TTCT, and TTCN as given in the equation $TTC_n = (TTCT - TO_{n-1}) \times TTCN$.

[0044]

Figure 13 shows a characteristic example of a TTCT calculation table, and Figure 14 shows a characteristic example of a TTCN calculation table. TTCT represents a piston cylinder wall temperature, and is related with the combustion temperature. Therefore, TTCT is determined from the calculation table of Figure 13 by using the product of the fuel injection quantity Te and the engine rotational speed Ne. TTCN represents an engine oil flow velocity for heat transmission, and is determined from the calculation table of Figure 14 by using the engine rotational speed Ne.

[0045]

In S45, a heat release quantity TTA to the outside air is calculated by the equation $TTA_n = (TO_{n-1} - Ta) \times TTAVSP$. Ta represents an outside air temperature that is an output signal from the outside air temperature sensor 17, and TTAVSP represents a flow velocity for heat transmission determined from an output signal VSP (vehicle speed) from the vehicle speed sensor 18. Figure 15 shows a characteristic example of a TTAVSP calculation table.

[0046]

In S46, the oil temperature $TO_n$ is calculated by the equation $TO_n = TO_{n-1} + TTWn + TTC_n - TTA_n$. This equation is obtained by modeling a phenomenon that the engine oil is warmed by the engine cooling water and the piston cylinder due to combustion, and is cooled by wind due to vehicle running (and engine cooling water).

[0047]

The thus-obtained oil temperature TO is used to calculate the evaporation rate of oil-diluting fuel.

[0048]

In this embodiment, an example in which the oil temperature TO is predicted has been shown to provide the system at a low cost. However, to provide higher accuracy, it is optional to employ a temperature sensor to directly sense the engine oil temperature.

[0049]

Also, in this embodiment, the outside temperature Ta is used to cool the oil pan, and warm air from a radiator is neglected. However, in the case of a vehicle in which the warm air from the radiator is influential, it is possible to improve the accuracy by modifying Ta in consideration of the warm air from the radiator.

[0050]

The thus-constructed oil-diluting fuel quantity estimating apparatus estimates the oil-diluting fuel quantity OF of fuel mixing in the engine oil based on the cylinder wall temperature TC, engine rotational speed Ne, base fuel injection quantity Tp, and fuel injection quantity Te. Thereby, the oil-diluting fuel quantity can be estimated with high accuracy irrespective of the operating pattern and environment.

[0051]

The engine rotational speed Ne, base fuel injection quantity Tp, and fuel injection quantity Te are parameters

which are used in the existing engine control system. Besides, the cylinder wall temperature TC is estimated from the engine rotational speed Ne, fuel injection quantity Te, and engine cooling water temperature Tw. Therefore, the oil-diluting fuel quantity OF can be calculated at a low cost based on the existing engine control system.

[0052]

Next, a second embodiment of the present invention will be explained. In the second embodiment, the oil-diluting fuel quantity estimating apparatus in the above-described first embodiment is mounted on an engine carrying out the air-fuel ratio control, and a fuel injection pulse width Ti calculated by using the fuel injection quantity Te determined by the engine operating condition is corrected in accordance with the oil-diluting fuel quantity OF calculated by the oil-diluting fuel quantity estimating apparatus.

[0053]

Figure 16 is a flowchart showing a specific control flow in the second embodiment.

[0054]

In S51, the base fuel injection quantity Tp is calculated. The base fuel injection quantity Tp is calculated by using the engine rotational speed Ne and the intake air quantity Qa obtained from the output of the air flowmeter 8 and by multiplying a per-engine-rotation intake air quantity (Qa/Ne) by a predetermined constant K. The base fuel injection quantity Tp is the basis of calculation

of the aforementioned fuel injection quantity Te and is a representative value of engine load.

[0055]

In S52, an air-fuel ratio correction coefficient KMR is calculated from a map of the engine rotational speed Ne and the throttle valve opening degree. The map for calculating the air-fuel ratio correction coefficient KMR is stored in advance in the ECU 12.

[0056]

In S53, a water temperature enrichment coefficient KTW is calculated from a table of the engine cooling water temperature Tw. The table for calculating the water temperature enrichment coefficient KTW is stored in advance in the ECU 12.

[0057]

In S54, a target fuel-air ratio equivalence quantity TFBYA is calculated by using the oil fall rate C and load correction ratio D calculated by the aforementioned oil-diluting fuel quantity estimating apparatus as given by the equation TFBYA = 1 + KMR + KTR + (C x D x GUB). In this equation, GUB is set as GUB = (H1 + H2) / H2, where H1 is a quantity discharged into the exhaust system, and H2 is a quantity of oil-diluting fuel. GUB is equal to about 1.6, for example. Some of fuel adhering to the cylinder wall is scraped off by the piston and turns to the oil-diluting fuel that dilutes the engine oil, and some of fuel adhering to the cylinder wall is discarded from the exhaust system

without being burned. For this reason, the predetermined constant GUB is used for multiplication to take into account the fuel discarded from the exhaust system without being used in combustion.

[0058]

In S55, the fuel injection quantity Te is calculated by using the equation $Te = Tp \times TFBYA \times \alpha \times \alpha m \times KTR$. In this equation, $\alpha$ is an air-fuel ratio feedback correction coefficient, which is calculated based on an output signal sent from the oxygen concentration sensor 13 by another flowchart apart from the flowchart. Moreover, $\alpha m$ is an air-fuel ratio learning correction coefficient calculated based on $\alpha$, and KTR is a transient correction coefficient representing a correction quantity of fuel flowing on the wall.

[0059]

In S56, the fuel injection pulse width Ti, which is a pulse width required to inject the aforementioned fuel injection quantity Te, is calculated by using the equation $Ti = Te \times KWJ + Ts$. In this equation, KWJ is an injection quantity correction coefficient, and Ts is an ineffective pulse width for correction of a difference between the energizing time of the fuel injection valve 11 and the actual fuel injection time.

[0060]

In S57, the fuel injection pulse width Ti is output to control the fuel injection valve 11 to carry out the fuel

injection with the fuel injection pulse width Ti.

[0061]

In the above-described second embodiment of the present invention, it is possible to reduce the memory capacity of the ECU 12 and to reduce the manpower for adaptation by making the enrichment correction for unburned fuel by using the maps and tables for the oil-diluting fuel quantity estimation in common.

[0062]

In the second embodiment, the fuel injection pulse width Ti is corrected by paying attention to the increase quantity A of the oil-diluted fuel quantity. However, it is possible to correct the fuel injection pulse width Ti by paying attention to the increase quantity A and the decrease quantity B. Also, in the MTCH map (Figure 9) and the KTC map (Figure 10), it is possible to use the fuel injection quantity Te in place of the base fuel injection quantity Tp. In this case, the oil-diluted fuel quantity is corrected in accordance with the fuel injection quantity Te actually injected for the engine.

[0063]

Next, a third embodiment of the present invention will be explained.

[0064]

At present, engines of many motor vehicles can burn gasoline containing alcohol of a low concentration. Also, in recent years, a vehicle called a flexible fuel vehicle

(FFV) has widely been known which can run not only on gasoline but also on a blended fuel of various compositions of alcohol and gasoline.

[0065]

Thereupon, in the third embodiment, there is explained a case where the techniques of the above-described first and second embodiments are applied to an internal combustion engine using a fuel containing alcohol.

[0066]

Alcohol fuel requires a large fuel injection quantity to obtain the same equivalence ratio as compared with gasoline because of the number of atoms of C (carbon), H (hydrogen), and O (oxygen). Therefore, the concentration of alcohol in the fuel is predicted accurately as quickly as possible by utilizing the detection value of the oxygen concentration sensor 13.

[0067]

Figure 17 is a flowchart showing a control flow for estimating the alcohol concentration in the third embodiment.

[0068]

In S61, the air-fuel ratio feedback correction coefficient α calculated based on an output signal sent from the oxygen concentration sensor 13 is read from another flowchart apart from the flowchart.

[0069]

In S62, it is judged whether or not a learning condition is satisfied. If the learning condition is

satisfied, the control proceeds to S63, where a map value in an $\alpha m$ calculation map for each operating region is rewritten. If the learning condition is not satisfied, the control proceeds directly to S64 without performing the $\alpha m$ map value rewriting operation.

[0070]

In S64, a value of $\alpha m$ in each operating region is determined by referring to the current $\alpha m$ map for each operating region.

[0071]

Next, in S65, it is judged whether or not the oil-diluting fuel quantity OF calculated in the flowchart of Figure 2 is smaller than a predetermined estimation permitting dilution quantity LOF#.

[0072]

In S66, it is judged whether or not the absolute value of the variation quantity COF calculated in the flowchart of Figure 2 is smaller than a predetermined estimation permitting dilution variation quantity LCOF#.

[0073]

In S65 and S66, if both of the oil-diluting fuel quantity OF and the absolute value of the variation quantity COF are smaller than the target values (LOF# and LCOF#), respectively, the control transfers to a path permitting the alcohol concentration estimation on the assumption that the influence of fuel evaporated from the engine oil is little. The alcohol concentration estimation requires another

permitting condition (S67). In this embodiment, when conditions such as the engine cooling water temperature, elapsed time after the start of engine, a progress of air-fuel ratio learning control, and the record of past refueling are met, the alcohol concentration is estimated (S68).

[0074]

In S68, an average of αm in representative speed load regions of αm in operating regions is calculated. Specifically, the average of αm is determined from the values of four or so speed load regions, and the alcohol concentration is calculated from a table shown in Figure 17 by using the above result. In this case, regions which are used relatively frequently by the engine and in which the intake air quantity is not so small are selected as the aforementioned four regions. By doing so, regions having a relatively large intake air quantity, which secures the frequency of learning and is less liable to be subjected to an influence of oil-diluting fuel evaporating from the engine oil, are selected.

[0075]

The characteristic shown in Figure 18 has a dead band in which the alcohol concentration is not changed with respect to a change in the average of αm. This characteristic is set to use a stable control value (a control constant) when gasoline is inserted or when a standardized blended fuel (gasoline-alcohol fuel) is always

inserted. The aforementioned control value includes at least one of a control constant about the ignition timing, constant about correction of wall flow of fuel, constant about ternary point adjustment of what is called $\lambda$ control, and constant about cold enrichment. The dead band is provided because the repeatability of emission becomes poor if these are varied.

[0076]

In the above-described third embodiment, the alcohol concentration in the fuel can be estimated quickly, and hence a flexible fuel vehicle having good operability and emission control can be provided.

[0077]

Technical concepts of the present invention capable of being grasped from the above-described embodiments are listed together with the effects of the present invention.

[0078]

(1) The oil-diluting fuel estimating apparatus includes increase quantity calculating means for calculating the increase quantity of oil-diluting fuel that leaks out through the clearance between the piston and the cylinder and dilutes the engine oil, from the engine temperature, engine rotational speed, and engine load, and oil-diluting fuel quantity calculating means for calculating the quantity of oil-diluting fuel that dilutes the engine oil by summing up the increase quantities of oil-diluting fuel calculated by the increase quantity calculating means. Therefore, the

oil-diluting fuel quantity can be estimated with high accuracy.

[0079]

(2) The oil-diluting fuel estimating apparatus includes increase quantity calculating means for calculating the increase quantity of oil-diluting fuel that leaks out through the clearance between the piston and the cylinder and dilutes the engine oil, decrease quantity calculating means for calculating the decrease quantity of oil-diluting fuel quantity from the engine temperature and engine rotational speed, and oil-diluting fuel quantity calculating means for calculating the quantity of oil-diluting fuel that dilutes the engine oil by summing up the oil-diluting fuel increase quantity calculated by the increase quantity calculating means and the oil-diluting fuel decrease quantity calculated by the decrease quantity calculating means. Therefore, the evaporation quantity of engine oil from the oil-diluting fuel is also taken into account, by which the quantity of oil-diluting fuel can be estimated with higher accuracy.

[0080]

(3) In the oil-diluting fuel estimating apparatus described in item (1) or (2), the engine temperature in the increase quantity calculating means is the cylinder wall temperature. The cylinder wall temperature is a factor that exerts a great influence on the adhesion of fuel injected into the combustion chamber and vaporization thereof, so

that by using this value, the accuracy of estimation of oil-diluting fuel quantity is further improved.

[0081]

(4) In the oil-diluting fuel estimating apparatus described in item (2), the engine temperature in the decrease quantity calculating means is the engine oil temperature. Since the oil-diluting fuel is present in the engine oil, the engine oil temperature is a factor that exerts a great influence on the evaporation of oil-diluting fuel from the engine oil. Therefore, by using this value, the accuracy of estimation of oil-diluting fuel quantity is further improved.

[0082]

(5) In the oil-diluting fuel estimating apparatus described in any one of items (1) to (4), an alcohol concentration calculation permitting condition for permitting the calculation of alcohol concentration is set in accordance with the oil-diluting fuel quantity when a fuel in which alcohol is mixed in gasoline is used. Therefore, the inflow of oil-diluting fuel into the engine oil and the evaporation of oil-diluting fuel from the engine oil become constant, so that the alcohol concentration can be calculated accurately.

[0083]

(6) In the oil-diluting fuel estimating apparatus described in item (5), when by the alcohol concentration calculation permitting condition, at least either one of the

condition that the oil-diluting fuel quantity is not larger than a predetermined value and the condition that a variation in oil-diluting fuel quantity is not larger than a predetermined value is satisfied, the calculation of alcohol concentration is permitted.

[0084]

(7) In the oil-diluting fuel estimating apparatus described in any one of items (1) to (6), the oil-diluting fuel quantity is corrected in accordance with the quantity of fuel injected actually from the engine.

[0085]

(8) The internal combustion engine control system corrects the fuel injection quantity in accordance with the oil-diluting fuel quantity calculated by the oil-diluting fuel estimating apparatus described in any one of items (1) to (6). Thereby, a proper air-fuel ratio can be realized.

[Brief Description of the Drawings]

[Figure 1]

An explanatory view showing a schematic configuration of an internal combustion engine control system in accordance with one embodiment of the present invention.

[Figure 2]

A flowchart showing a control flow in accordance with a first embodiment of the present invention.

[Figure 3]

A flowchart showing a control flow of a first subroutine shown in Figure 2.

[Figure 4]

An explanatory view showing a characteristic example of the MOFD map.

[Figure 5]

An explanatory view showing a characteristic example of a load correction table.

[Figure 6]

A flowchart showing a control flow of a second subroutine shown in Figure 2.

[Figure 7]

An explanatory view showing a characteristic example of the MOFU map.

[Figure 8]

A flowchart showing control of prediction of a cylinder wall temperature TC.

[Figure 9]

An explanatory view showing a characteristic example of the MTCH map.

[Figure 10]

An explanatory view showing a characteristic example of the KTC map.

[Figure 11]

A flowchart showing control of prediction of an oil temperature TO.

[Figure 12]

An explanatory view showing a characteristic example of a TTWS calculation table.

[Figure 13]

An explanatory view showing a characteristic example of a TTCT calculation table.

[Figure 14]

An explanatory view showing a characteristic example of a TTCN calculation table.

[Figure 15]

An explanatory view showing a characteristic example of a TTAVSP calculation table.

[Figure 16]

A flowchart showing a control flow in accordance with a second embodiment of the present invention.

[Figure 17]

A flowchart showing a control flow in accordance with a third embodiment of the present invention.

[Figure 18]

An explanatory view showing a characteristic example of an alcohol concentration calculation table.

[Expression of Reference Letters]

1 … engine body

2 … combustion chamber

3 … intake valve

4 … intake air passage

5 … exhaust valve

6 … exhaust passage

7 … air cleaner

8 … air flowmeter

9 ... throttle valve

11 ... fuel injection valve

12 ... engine control unit

13 ... oxygen concentration sensor

14 ... three-way catalyst

15 ... water temperature sensor

16 ... crank angle sensor

17 ... outside air temperature sensor

18 ... vehicle speed sensor

[Name of Document] Abstract

[Abstract]

[Problem] To estimate an oil-diluting fuel with high accuracy.

[Solution] An oil-diluting fuel estimating apparatus includes increase quantity calculating means for calculating the increase quantity of oil-diluting fuel that leaks out through a clearance between a piston and a cylinder and dilutes engine oil, from the engine temperature, engine rotational speed, and engine load, and oil-diluting fuel quantity calculating means for calculating the quantity of oil-diluting fuel that dilutes the engine oil by summing up the increase quantities of oil-diluting fuel calculated by the increase quantity calculating means.

[Selected Figure] None

[Name of Document] Drawings

[Figure 1]

I/O PORT

1 … ENGINE BODY

2 … COMBUSTION CHAMBER

3 … INTAKE VALVE

4 … INTAKE AIR PASSAGE

5 … EXHAUST VALVE

6 … EXHAUST PASSAGE

7 … AIR CLEANER

8 … AIR FLOWMETER

9 … THROTTLE VALVE

11 … FUEL INJECTION VALVE

12 … ENGINE CONTROL UNIT

13 … OXYGEN CONCENTRATION SENSOR

14 … THREE-WAY CATALYST

15 … WATER TEMPERATURE SENSOR

16 … CRANK ANGLE SENSOR

17 … OUTSIDE AIR TEMPERATURE SENSOR

18 … VEHICLE SPEED SENSOR

[Figure 2]

S1: CALCULATE INCREASE QUANTITY A OF OIL-DILUTING FUEL QUANTITY (FIRST SUBROUTINE)

S2: CALCULATE DECREASE RATE B OF OIL-DILUTING FUEL QUANTITY (SECOND SUBROUTINE)

S3: CALCULATE VARIATION QUANTITY COF

$COF = A - B \times OF_{n-1}$

S4: CALCULATE OIL-DILUTING FUEL QUANTITY OF

$OF = OF_{n-1} + COF$

[Figure 3]

S11: DETERMINE OIL FALL RATE C FROM MOFD MAP

S12: DETERMINE LOAD CORRECTION RATIO D FROM LOAD CORRECTION TABLE

S13: INCREASE QUANTITY $A = Te \times C \times D \times Ne$

[Figure 4]

MOFD MAP

TEMPERATURE TC

LOW

HIGH

[Figure 5]

LOAD CORRECTION TABLE

[Figure 6]

S21: DETERMINE DECREASE RATE B FROM MOFU MAP

[Figure 7]

MOFU MAP

TEMPERATURE TO

HIGH

LOW

[Figure 8]

S31: STARTING TIME OR ECU FIRST ENERGIZATION TIME ?

S33: FUEL CUTOFF ?

S35: DETERMINE TEMPERATURE INCREASE BALANCE TEMPERATURE TCH FROM MTCH MAP

S36: DETERMINE TEMPERATURE CHANGE RATE (TIME CONSTANT) KTC FROM KTC MAP

S37: CALCULATE PREDICTED TEMPERATURE DTC

$$DTC_n = DTC_{n-1} + (TCH - DTC_{n-1}) \times KTC$$

[Figure 9]

MTCH MAP

Tp (LOAD)

HIGH

LOW

[Figure 10]

KTC MAP

HIGH

LOW

[Figure 11]

S41: STARTING TIME OR ECU FIRST ENERGIZATION TIME ?

S43: READ TTWS FROM MAP, AND CALCULATE HEAT FLOW QUANTITY TTW OF ENGINE OIL AND COOLING WATER

$$TTW_n = (Tw - TO_{n-1}) \times TTWS$$

S44: READ TTCT AND TTCN FROM MAPS, AND CALCULATE HEAT FLOW QUANTITY TTC OF ENGINE OIL AND COMBUSTION

$TTC_n = (TTCT - TO_{n-1}) \times TTCN$

S45: READ FLOW VELOCITY TERM TTAVSP FOR HEAT TRANSMISSION FROM MAP, AND CALCULATE HEAT RELEASE QUANTITY TTA TO OUTSIDE AIR

$TTA_n = (TO_{n-1} - Ta) \times TTAVSP$

[Figure 12]

TTWS CALCULATION TABLE

[Figure 13]

TTCT CALCULATION TABLE

[Figure 14]

TTCN CALCULATION TABLE

[Figure 15]

TTAVSP CALCULATION TABLE

[Figure 16]

S51: CALCULATE BASE FUEL INJECTION QUANTITY Tp

S52: CALCULATE AIR-FUEL RATIO CORRECTION COEFFICIENT KMR FROM ENGINE ROTATIONAL SPEED AND THROTTLE VALVE OPENING DEGREE

S53: CALCULATE WATER TEMPERATURE ENRICHMENT COEFFICIENT KTW FROM COOLING WATER TEMPERATURE Tw

S54: CALCULATE TARGET FUEL-AIR RATIO EQUIVALENCE QUANTITY TFBYA BY USING OIL FALL RATE C, LOAD CORRECTION RATIO D, AND CORRECTION COEFFICIENT GUB

$$TFBYA = 1 + KMR + KTR + (C \times D \times GUB)$$

S55: CALCULATE FUEL INJECTION QUANTITY Te

$$Te = Tp \times TFBYA \times \alpha \times \alpha m \times KTR$$

S56: CALCULATE FUEL INJECTION PULSE WIDTH Ti

$$Ti = Te \times KWJ + Ts$$

S57: OUTPUT Ti

[Figure 17]

S61: READ $\alpha$

S62: LEARNING CONDITION SATISFIED ?

S63: REWRITE $\alpha m$ MAP VALUE

S64: REFER TO $\alpha m$ MAP

S67: ANOTHER PERMITTING CONDITION SATISFIED ?

S68: ESTIMATE ALCOHOL CONCENTRATION FROM AVERAGE OF $\alpha m$ BY USING MAP

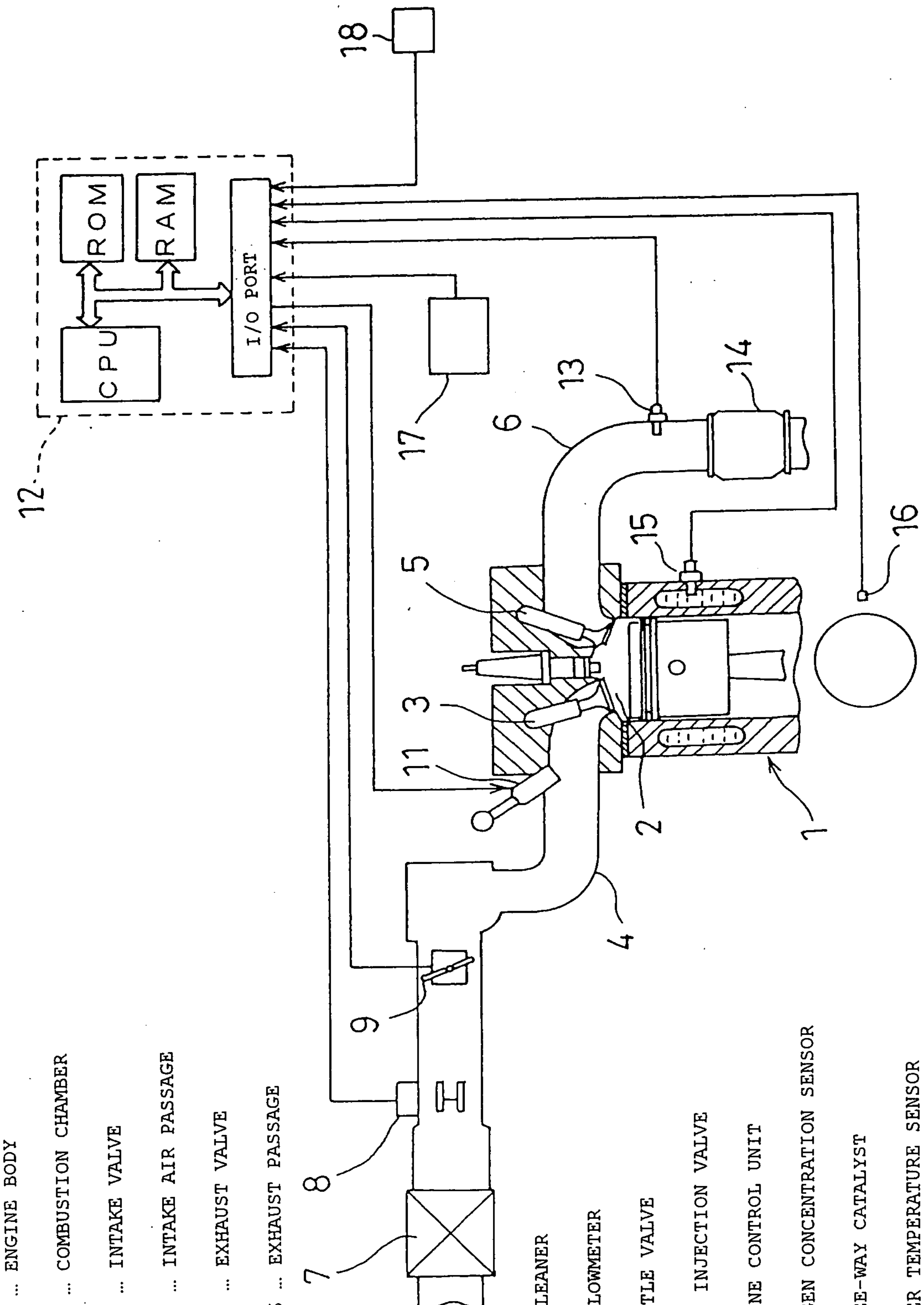
[Figure 18]

ALCOHOL CONCENTRATION ALC

AVERAGE OF $\alpha m$

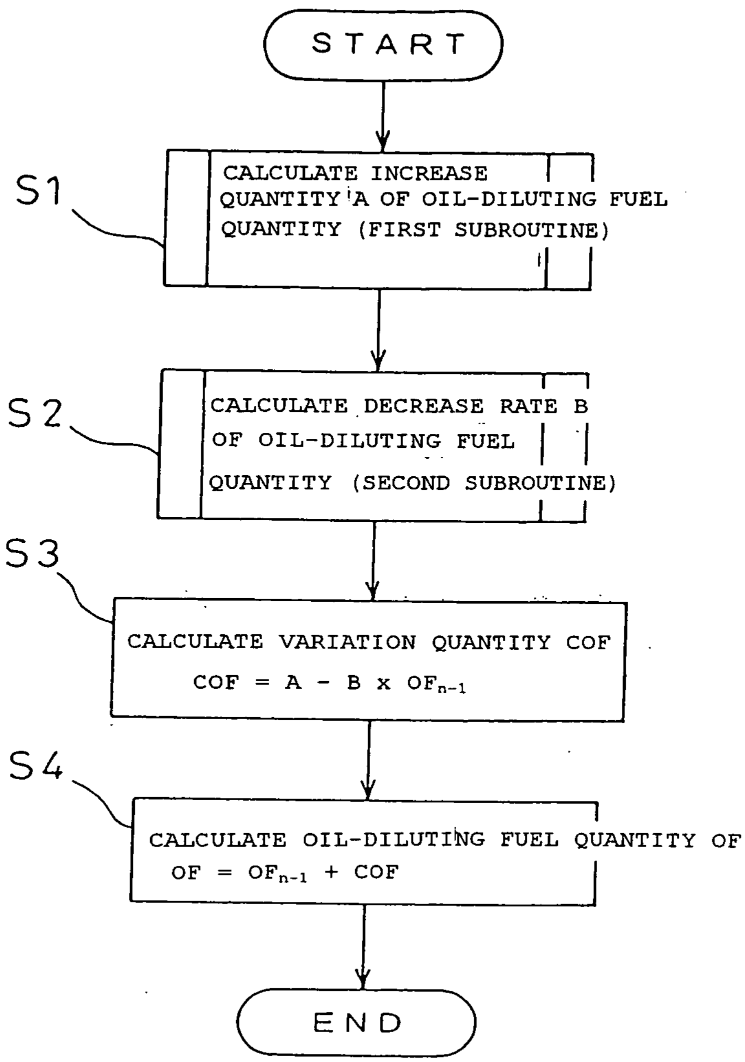
[Name of Document]　Drawings

[Figure 1]

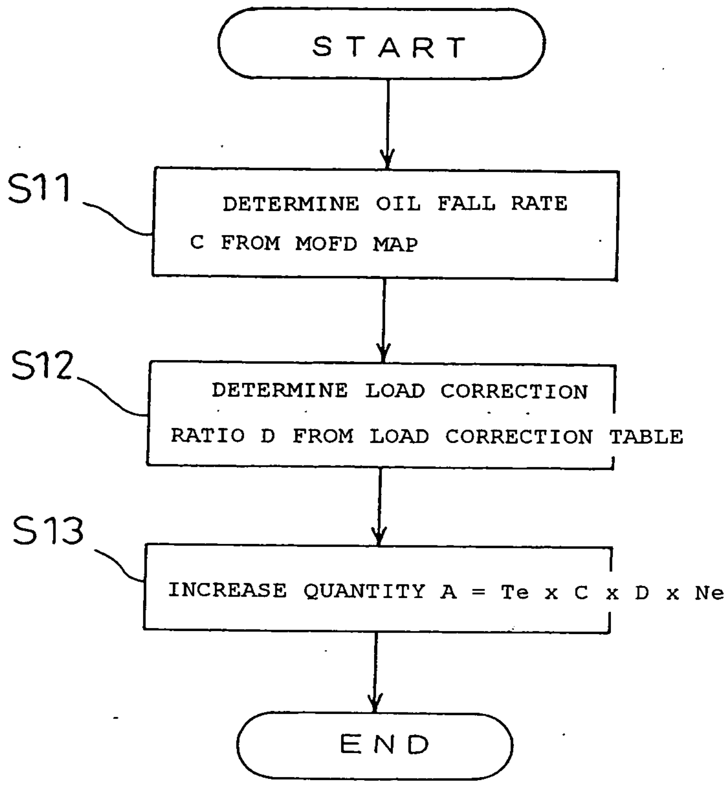



1 ... ENGINE BODY
2 ... COMBUSTION CHAMBER
3 ... INTAKE VALVE
4 ... INTAKE AIR PASSAGE
5 ... EXHAUST VALVE
6 ... EXHAUST PASSAGE
7 ... AIR CLEANER
8 ... AIR FLOWMETER
9 ... THROTTLE VALVE
11 ... FUEL INJECTION VALVE
12 ... ENGINE CONTROL UNIT
13 ... OXYGEN CONCENTRATION SENSOR
14 ... THREE-WAY CATALYST
15 ... WATER TEMPERATURE SENSOR
16 ... CRANK ANGLE SENSOR
17 ... OUTSIDE AIR TEMPERATURE SENSOR
18 ... VEHICLE SPEED SENSOR

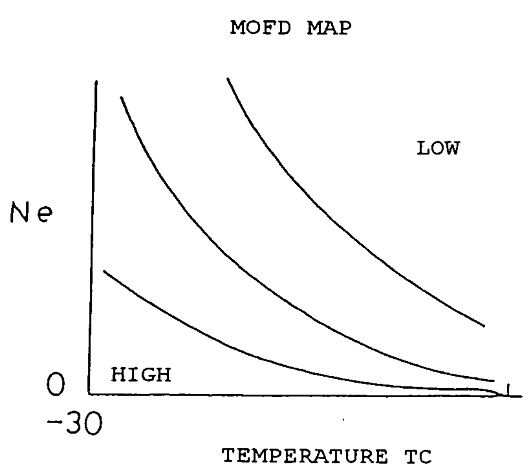
[Figure 2]


START
S1
CALCULATE INCREASE QUANTITY A OF OIL-DILUTING FUEL QUANTITY (FIRST SUBROUTINE)
S2
CALCULATE DECREASE RATE B OF OIL-DILUTING FUEL QUANTITY (SECOND SUBROUTINE)
S3
CALCULATE VARIATION QUANTITY COF
COF = A - B x OF$_{n-1}$
S4
CALCULATE OIL-DILUTING FUEL QUANTITY OF
OF = OF$_{n-1}$ + COF
END

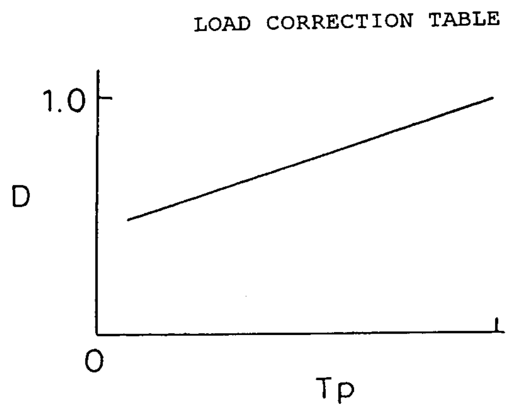
[Figure 3]



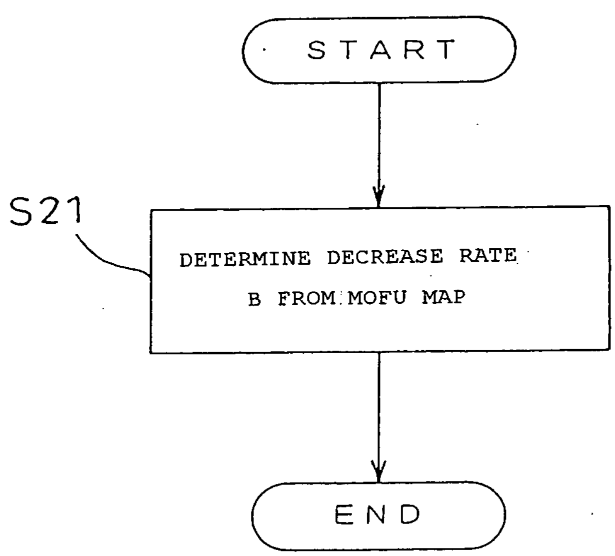

[Figure 4]



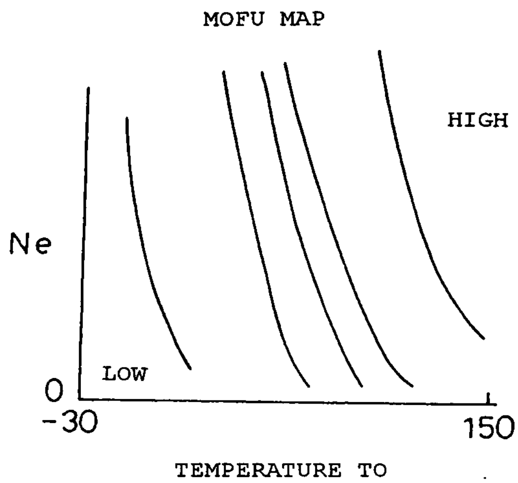
[Figure 5]



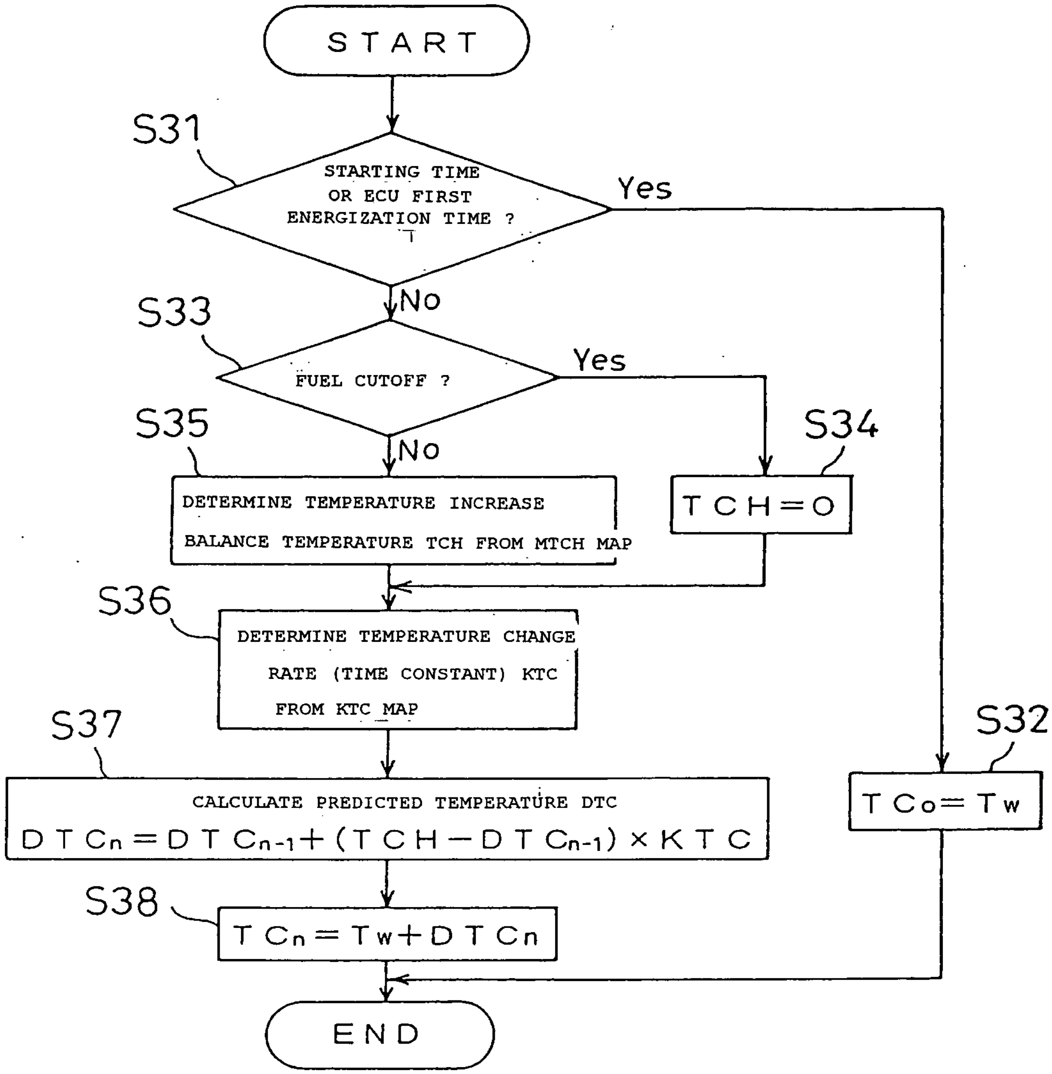

[Figure 6]



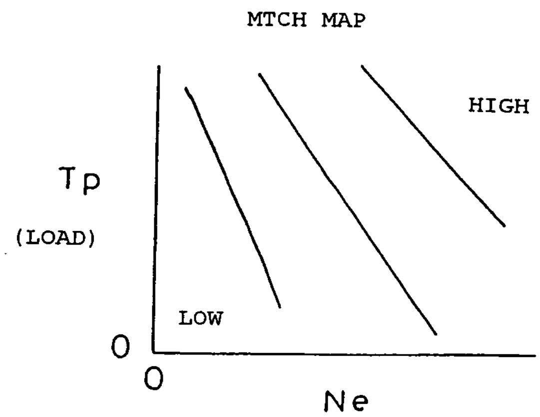
[Figure 7]



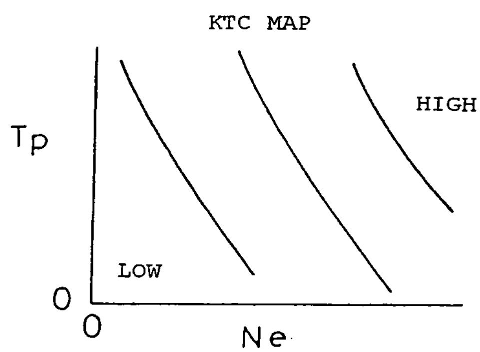
[Figure 8]


START
S31
STARTING TIME
OR ECU FIRST
ENERGIZATION TIME ?
Yes
No
S33
FUEL CUTOFF ?
Yes
No
S35
DETERMINE TEMPERATURE INCREASE
BALANCE TEMPERATURE TCH FROM MTCH MAP
S34
TCH=0
S36
DETERMINE TEMPERATURE CHANGE
RATE (TIME CONSTANT) KTC
FROM KTC MAP
S37
CALCULATE PREDICTED TEMPERATURE DTC
$DTC_n = DTC_{n-1} + (TCH - DTC_{n-1}) \times KTC$
S32
$TC_o = Tw$
S38
$TC_n = Tw + DTC_n$
END

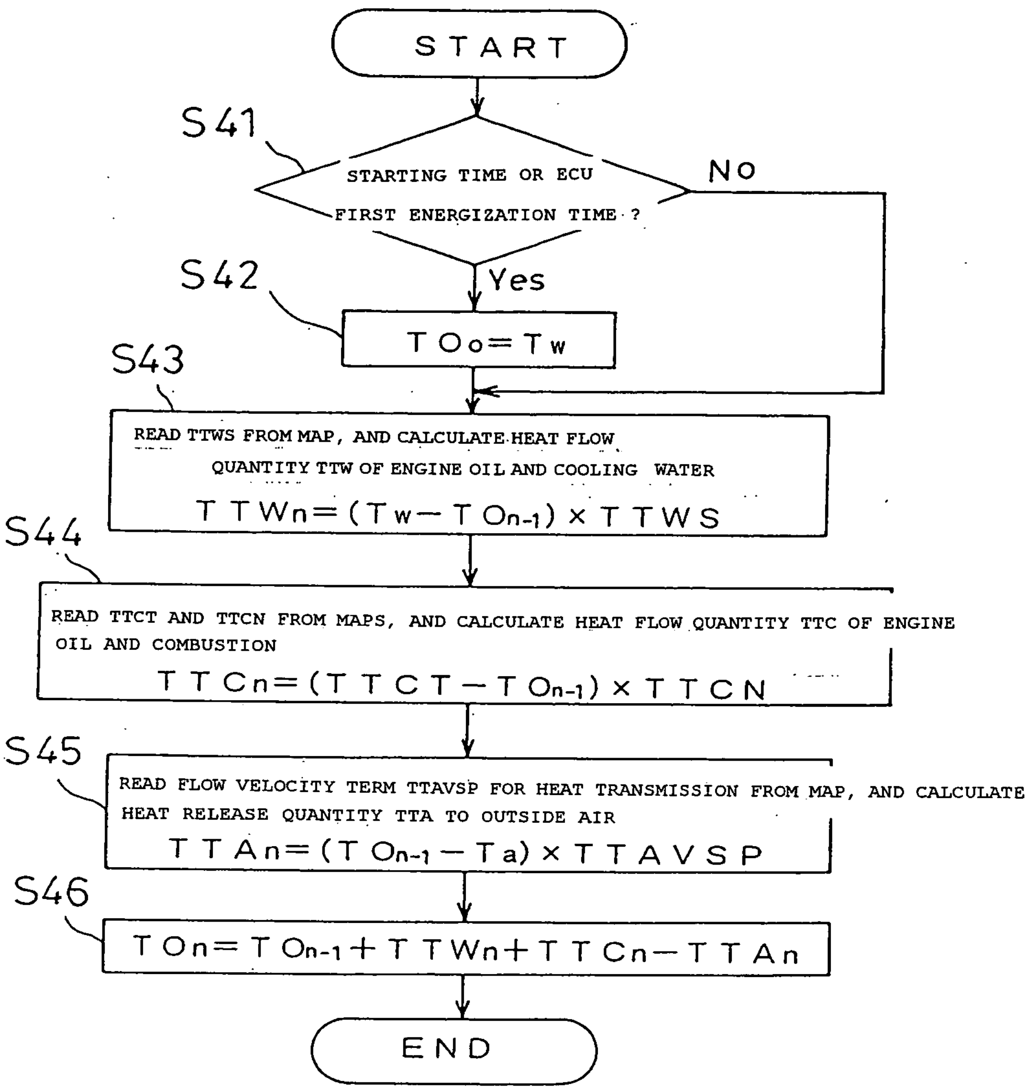
[Figure 9]



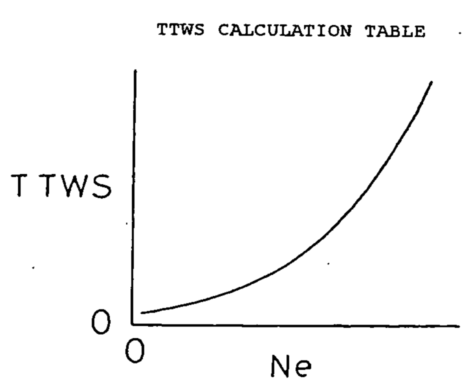

[Figure 10]



[Figure 11]

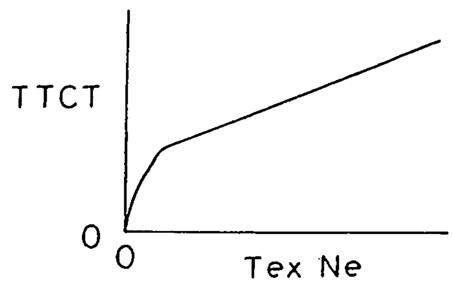



[Figure 12]



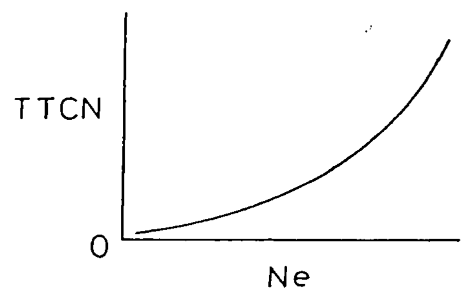
[Figure 13]

TTCT CALCULATION TABLE



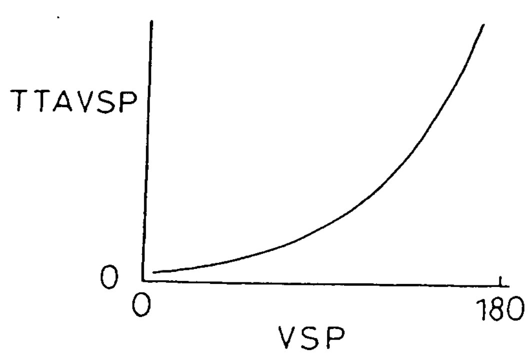

[Figure 14]

TTCN CALCULATION TABLE

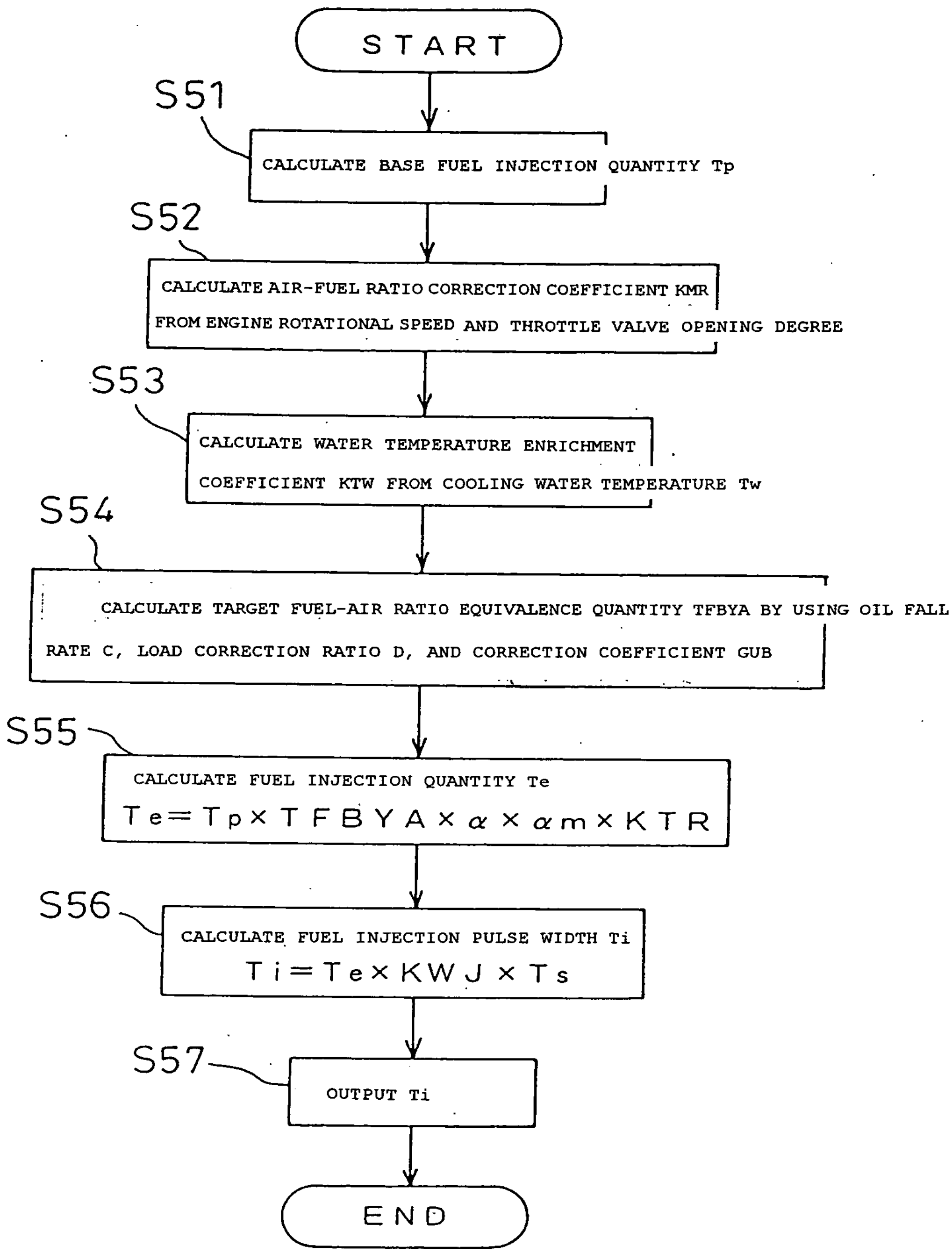



[Figure 15]

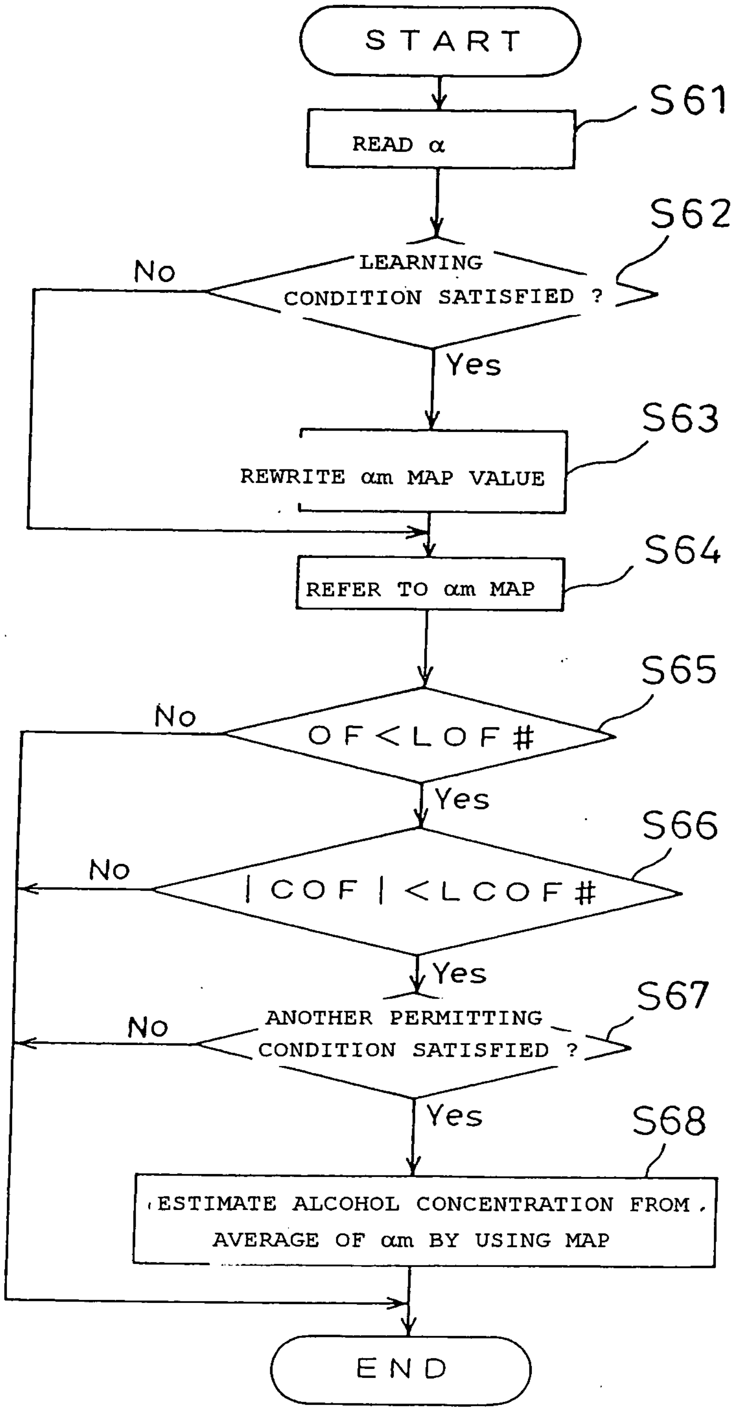
TTAVSP CALCULATION TABLE



[Figure 16]


START
S51
CALCULATE BASE FUEL INJECTION QUANTITY Tp
S52
CALCULATE AIR-FUEL RATIO CORRECTION COEFFICIENT KMR FROM ENGINE ROTATIONAL SPEED AND THROTTLE VALVE OPENING DEGREE
S53
CALCULATE WATER TEMPERATURE ENRICHMENT COEFFICIENT KTW FROM COOLING WATER TEMPERATURE Tw
S54
CALCULATE TARGET FUEL-AIR RATIO EQUIVALENCE QUANTITY TFBYA BY USING OIL FALL RATE C, LOAD CORRECTION RATIO D, AND CORRECTION COEFFICIENT GUB
S55
CALCULATE FUEL INJECTION QUANTITY Te
Te＝Tp×TFBYA×α×αm×KTR
S56
CALCULATE FUEL INJECTION PULSE WIDTH Ti
Ti＝Te×KWJ×Ts
S57
OUTPUT Ti
END

[Figure 17]


START
READ α
S61
LEARNING CONDITION SATISFIED ?
S62
No
Yes
REWRITE αm MAP VALUE
S63
REFER TO αm MAP
S64
OF<LOF#
S65
No
Yes
|COF|<LCOF#
S66
No
Yes
ANOTHER PERMITTING CONDITION SATISFIED ?
S67
No
Yes
ESTIMATE ALCOHOL CONCENTRATION FROM AVERAGE OF αm BY USING MAP
S68
END

[Figure 18]